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## ARTICLE IX.

*On some of the Results of a Series of Experiments relative to different parts of Gunnery.  
By Captain Robert F. Stockton, of the United States Navy. Communicated by Profes-  
sor Henry. Read June 19th, 1846.*

THE experiments of which the present communication is intended to give an account of some of the results, were instituted by permission of the Navy Department, and were supplementary to those previously ordered, by the same authority, to be made with the large guns of the steamer Princeton.

The results now presented to the society relate to the three following questions, viz.

1. Is a gun more liable to burst with a space left between the powder and shot, than when the latter is rammed home?
2. What is the effect, in reference to the tendency of bursting, of increasing the number of shot to be fired from the gun at the same discharge?
3. What part of the gun is exposed to the greatest internal pressure from the explosion of the powder?

I. It has been stated by the highest authorities on gunnery, and it seems to be generally admitted, that a space left between the powder and the ball greatly increases the danger of bursting.

“If,” says Mr. Babbage, in his interesting work on the economy of manufactures, “in loading a gun a space be left between the wadding and the charge, the gun either recoils violently or bursts.” This opinion appears to have been first advanced by Robins, and was based on some incidental observations made in the course of his experiments on gunnery. Various hypotheses have been proposed for its explanation. Mr. Babbage refers it to the difference of time in the passage of a wave, or the effect of an impulse, through air and through metal. Poisson, we believe, adopts the same explanation, while Robins attributes the effect to the momentum which the generated gas acquires before it reaches the ball. If the first explanation be true, it is difficult to see why a gun should not burst as readily without a ball as with one; and, in the second explanation, we are at a loss to conceive how a sufficient momentum can be generated in a gas moving in a

space already filled with common air. None of the high authorities we have mentioned appear to doubt the truth of the fact which, from its paradoxical nature, and the contradictory explanations which have been given of it, would seem to require a more substantial basis than that on which it appears to rest. The experiments of Robins were on a small scale, with a musket barrel, and none of them appear to have been instituted expressly for the purpose of settling the point in question. It is true that the opinion would seem to be supported by common observation, for undoubtedly guns do burst more frequently in cases where the ball is not down on the powder, than under other circumstances, but it should be recollected that the bursting, in every instance of this kind, may be due to the fact that the ball is too large for the bore, and that in attempting to force it down, it becomes wedged in the gun, and thus its resistance to dislodgement is materially increased. A comparatively small force applied to push down a ball too large for the bore, would convert a portion of its spherical surface into the form of a cylinder, which, by increasing the points of contact, would increase the resistance: we are aware of the fact that ordinary friction does not increase with an increase of rubbing surface, the total pressure remaining the same, but in the case of the ball the increase of the surface of contact increases the wedging, which must increase the resistance in the same proportion. From the foregoing considerations, the author of this paper was led to doubt the truth of the proposition, and to institute a series of experiments which should give it a more thorough test than any to which it before had been subjected.

For this purpose, a number of guns, of a calibre two inches in diameter—thirty-five inches long; of a uniform thickness of metal of one inch around the bore, and two inches of solid metal behind the bottom of the cavity, were cast from the same fount of iron—and were, consequently, nearly of the same strength. The weight of each was between ninety-three and ninety-six pounds, and they were secured, in succession, to a large block of timber, for the purpose of bursting. The charge consisted of cannon powder done up in the usual way, in light flannel cartridges; no wads were used, and the ball covered with a coating of felt, to lessen the windage, was placed in contact with the end of the cartridge, or at different distances from the same, the intervening space being occupied only with air. In all cases of a variation in the charge of powder, an increase was made of one-fourth of an ounce each time, until the desired effect was produced. The following are the particulars of the several experiments.

1. In the first experiment, the bursting of the gun took place at the first discharge, with seven ounces of powder, and the ball in contact with the cartridges. A smaller charge would have been first used, had it not been supposed, from some previous experiments with another set of guns, that this piece would have stood the quantity of powder with which it was loaded.

2. In another gun, the ball was constantly placed in contact with the cartridge. The firing was commenced with five ounces of powder, and the bursting took place at the fifth discharge, with six and a quarter ounces.

3. The ball in the next gun was placed first at twelve inches from the powder, then at four inches, and lastly in contact with the same. The experiment commenced with six ounces and a quarter of powder, and the explosion took place at the sixth discharge, with

six ounces and three quarters, the ball being in contact with the cartridge. It will be perceived, by this experiment, that the gun had, previous to bursting, withstood the force of two discharges of the same quantity of powder, with the ball at a distance from the cartridge.

4. In the next gun, the ball each time was placed at the distance of two inches from the end of the cartridge; the charge was regularly increased from six and a quarter ounces, and the bursting took place at the seventh discharge, with eight ounces of powder.

5. In the next experiment the ball was constantly placed at the distance of six inches from the end of the cartridge, and the charge regularly increased until the bursting was produced, with nine ounces and three quarters of powder.

6. The ball, in the next experiment, was placed alternately at the distance of twelve and four inches from the cartridge. The firing commenced with six ounces of powder, and was regularly increased until the gun burst. The last charge was seven ounces and three quarters, and the ball at the distance of four inches from the cartridge.

7. In the next experiment, the gun was loaded with two balls, placed at the distance of twelve, and four inches from the cartridge, and also in contact with the same. The balls were fired in succession, with the same charge, from each position, and when the process was repeated with an increased charge, the bursting took place at the sixth discharge, with four and a half ounces of powder, and the balls in contact with the cartridge. In this case also the gun burst, after having withstood previously two discharges of the same quantity of powder, and a space between the balls and the cartridge.

Another set of guns had previously been cast of the same weight and dimensions of those we have described, but of metal of finer texture, and greater tenacity. In reference to the question under consideration, two of these guns were burst in succession; the following are the particulars and results:—

1. The first was charged in succession with one ball, placed in contact with the powder, the charge being regularly increased from seven ounces. The bursting took place with nine ounces and a quarter.

2. The other gun was fired in succession with the ball placed at the distance of twenty-one inches and nine inches from the cartridge, and in contact with the same. The experiment began with a charge of seven ounces, and the bursting was produced with eight ounces and three quarters, the ball being in contact with the powder.

The general results of these experiments are the same as those with the other set of guns. The bursting took place with the ball in contact with the powder, and in both cases after the gun had withstood two discharges of the same quantity of powder with a space between the cartridge and the ball.

The following is a recapitulation of the results with the first set of guns.

With shot rammed home, from the mean of three experiments, the bursting charge was	$6\frac{2}{3}$ oz.
With space of two inches, bursting charge, . . . . .	8 oz.
With space of four inches, . . . . .	$7\frac{3}{4}$ oz.
With space of six inches, . . . . .	$9\frac{1}{4}$ oz.

(1.) By an examination of all the results, it will be seen that the guns invariably burst with a smaller charge when the ball was nearer the powder than when it was at a distance. The average bursting charge from three sets of experiments with the balls in contact with the powder is six ounces and three quarters; while, with a space between, the average charge, to produce the same effect, is eight ounces and a half.

(2.) In three cases of the four guns in which the position of the balls was varied, the bursting took place with the ball in contact with the powder after the gun had twice sustained the force of the discharge with the same quantity of powder with a space between the ball and the charge; and in the fourth case, (experiment 6,) in which the ball was placed alternately at the distance of twelve and four inches, the bursting took place with the shot at the shortest distance, after the gun had previously withstood the same charge at the greater distance.

It may be mentioned, that the range or distance to which the ball was thrown horizontally, before striking the ground, was greater in all cases where the shot was down on the powder than in those in which a space was left between, also when the shot was in contact with the powder, the recoil, as indicated by the motion of the timber to which the gun was fastened, was less than when the shot was rammed home. This result is also at variance with the popular belief in reference to the subject. From these results it therefore appears, that so far from increasing the tendency of a gun to burst by leaving a space between the ball and the powder, the danger is considerably diminished by such an arrangement.

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II. In reference to the second question, the effect of increasing the number of shot, we have the following results from the two sets of guns:—

*From the first set.*

1. With one gun charged with a single ball in contact with the powder, the bursting charge was six ounces and two-thirds.
2. With another gun, with four balls, all home, the bursting charge was three ounces and three-fourths.
3. With the next gun, charged with nine balls, all home, the bursting charge was three ounces and a quarter.

*From the second set.*

1. The first of these guns was burst without shot, the quantity of powder being regularly increased, the effect took place with sixteen ounces.
2. Another gun, charged with one ball, in contact with the powder, burst with nine and a quarter ounces.
3. The next, also with one ball in contact with the powder, burst with eight ounces and three quarters. The average of the last two being nine ounces.
4. Also another gun of the same set, charged with two balls sent home, burst with six and a half ounces.
5. Another of the same set, loaded with five balls, all home, burst with four ounces.

By a comparison of the last set of experiments made with the guns of greater tenacity of metal, it appears that the bursting charges are nearly as the square root of the number of balls inversely. And this would seem to be in accordance with the well-established fact, that, with a constant pressure, the time required to move a weight through a given distance, is as the square root of the weight.

The results of the experiments with the first set of guns are in general the same as those from the second set, although the deviation from the ratio of the square root of the number of balls is more considerable. The variation, however, is not greater than what might be expected from experiments of this kind. It will be perceived that some of the results of the experiments which were given under the head of the first question are repeated under the present head, and it may be proper to add, that the whole number of guns burst in these experiments was fourteen, and the number of discharges about three hundred.

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III. In reference to the third question, namely, what part of the gun is subjected to the greatest internal pressure at the moment of the discharge, the following experiments and observations are offered. For the purpose of ascertaining the relative pressure on the different parts of the interior, a series of holes were drilled through to the bore along each side of a number of the guns, and to these holes, in succession, a barrel six inches long was strapped, at right angles to the length of the piece, so that the velocity of the ball from this barrel, in different positions, would give the pressure required. The holes were six inches apart, and in order not to diminish too much the strength of the gun, those on one side were made in the middle between those on the opposite side. The gun was immovably fastened to a large block of timber, and to determine the velocity of the ball from the short barrel, and consequently the internal pressure, the whole was accurately levelled, and a horizontal line drawn at the height of the axis of the gun, on a target of pine plank placed at the distance of ten yards. The deflection of the ball from this line being accurately measured by its mark on the target, the time of flight, and consequently the velocity, could be approximately calculated on the principles of falling bodies—also, for the sake of comparison, with the results furnished by the deflections, the depths of penetration of the balls into the pine plank of the target were accurately noted. The charge of the gun in all the experiments was the same, and consisted of two ounces of cannon powder, and one ball, placed in contact with the end of the cartridge. The holes were along the whole length of the bore of the gun; the first one being at about two inches from the end of the bore and a little behind the centre of the ball. Ten discharges were made in succession with the lateral barrel opposite the same hole, and the average distance of the marks of all the balls on the target below the horizontal lines was taken as the measure of deflection. The series with each hole was several times repeated until the whole number of shots fired exceeded a thousand.

The general result was, that the least deflection and the greatest penetration were produced when the side barrel was fired from the hole nearest the powder—that the velocity diminished, in a ratio not determined, as the barrel was advanced towards the muzzle.

From these results it is inferred that the greatest internal pressure is on that part of the gun occupied by the powder, and as a fact in accordance with this inference, it may be mentioned that in all cases of the bursting of a gun, the fracture was confined to the part between the bottom of the bore and the position of the outer side of the last ball. The solid britch end was always broken short off at the bottom of the bore, and presented in every instance a remarkable similarity of appearance. Looking in the direction of the axis of the bore, the surface of fracture of the solid end was seen divided into three nearly equal sections, by three ridges nearly in the direction of the radii, with concave surfaces between them. From an examination of all the fragments, the fact appeared to be established that the fracture always began in three lines near the britch, but that, on advancing towards the muzzle, it frequently wedged out into four, and sometimes more, lines.

A number of other questions have occupied the attention of the author of these experiments, and the other results of his investigations may, perhaps, be hereafter presented to the society, should the present article be deemed of sufficient interest to warrant another communication of a similar character.